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ii; 34 p.
tables
graphs
diagrams

Small Hydropower Series No. 5

BRIEF REPORT
ON
THE OLADE TECHNICAL MANUAL ON THE TYPICAL DESIGN AND FABRICATION OF EQUIPMENT AND MACHINERY FOR SMALL HYDROPOWER STATIONS (SHP)

Prepared in cooperation with
the Latin-American Energy Organization (OLADE)

UNITED NATIONS
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Preface

This technical summary is presented as one of the United Nations Industrial Development Organization (UNIDO) publications in the Small Hydropower Series. Iy provides information about the main purpose of the *Manual on Typical Design and Fabrication of Equipment and Machineries for Small Hydropower Stations* prepared by the Latin American Energy Organization (OLADE) in co-operation with UNIDO. The Manual presents a guide on turbine design for small hydropower as well as provides standardized specifications that take into consideration the industrial set-up and characteristics of potential markets in developing countries. Its contents respond to the need to provide and propagate the technological base required to produce and utilize SHP equipment for various types of turbines and speed regulators.

The Manual comprises six volumes. The first three deal with the design, standardization and manufacture of turbines for medium- and low-head applications, as follows:

Volume I • Michell-Banki turbines

Volume II • Pelton turbines

Volume III • Axial-flow (tubular) turbines

The last three volumes deal with design, standardization and construction of speed regulators of the main types:

Volume IV • Oleomechanical speed regulators

Volume V • Electric-electronic speed regulators with positive load control

Volume VI • Electric-electronic speed regulators with load dissipation

The large amount of knowledge and specific experience gained in developing countries by OLADE has made it possible to develop a technology that is suitable for the fabrication of SHP plants and to promote independent development of energy resources and capacities in these countries. The activities of OLADE and its programmes in this context aim at facilitating SHP development in aspects related to resource assessment, development planning, design and engineering. OLADE also provides advice on designing institutional schemes, training with respect to the operation and maintenance of SHP stations, and the transfer of experience when dealing with the acquisition of technologies and equipment and design and manufacturing in developing countries.

In order to create awareness of this important technology and facilitate the proper application of the *Manual*, it was decided to prepare a technical summary for distribution to the developing countries.

It is hoped that this technical summary will serve planners, project engineers, designers and manufacturers of SHP equipment and organizations dealing with design realization and operation of SHP and speed regulation equipment in developing countries to become familiar with the *Manual's* purpose and application areas and will generate the particular interest of potential users.

The technical summary is available in English, French and Spanish. Requests for additional copies of the technical summary and individual volumes or even the whole set of the comprehensive technical manual which is available in English and Spanish, should be addressed to:

Basic Technology Unit
Industrial Technology Promotion Division
Department for Industrial Promotion,
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Vienna International Centre
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INTRODUCTION

In the respective introductions to the six volumes of the Manual, OLADE rightly draws attention to the importance of hydro energy development in Latin America, but it is obvious that conditions exist in some African and Asian countries that would be particularly favourable for increased SHP development. The required technology is well-known, experience has been gained in a number of existing plants, project engineering capacity is available and manufacturing and construction capabilities have been developed. However, application of the above know-how has not been made sufficiently well-known. The total cost of realized plants worldwide has been high and has sometimes been too expensive. To date, standardization has only just begun to be recognized as an essential factor to ensuring economic and technical success of SHP.

The six volumes deal with two of the important elements of SHP namely:

(a) Turbines: i.e. the Michell-Banki, Pelton and Axial-flow types;

(b) Turbine speed regulation.

For the sake of clarity and brevity, the following comments do not follow the chapter-by-chapter approach of the OLADE volumes but have been rearranged as follows for both turbines and speed regulation:

- General remarks
- Design
- Standardization
- Manufacturing
- Additional remarks

I. TURBINES

A. General remarks

The three volumes on turbines deal with three of the most likely types of turbines to be utilized in SHP stations, i.e. the Michell-Banki, Pelton and Axial-flow types. The Manual does not include the Francis type of turbine.

If standardization is to be successful, it is essential that agreement be reached that for a given range of head and flow only one type of standardized turbine be chosen; the number of so-called standardized SHPs indicated in the notes is at present high, thus giving the designer a wider variety to choose from.

B. Design

Because of the large amount of information given, the distinction made in the Manual between hydraulic, detailed and mechanical design may at first sight appear unclear. However, taken as a whole, the design chapters intend to give planners, designers and manufacturers an idea of some of the tools they will need in order to realize SHPs. Some information is lacking, for example workshop drawings, while other information, e.g. theoretical calculation considerations, is perhaps too detailed.

However, of particular interest (we shall return to this point further on) is the part in the notes dealing with practical examples, for which use is made of information, calculations and recommendations made in earlier chapters. This point is discussed later

Tables 1 and 2 list the design information given as follows:

TABLE 1

Hydraulic Design		
Michell-Banki Turbines	**Pelton Turbines**	**Axial-flow Turbines**
Speed diagrams Injector geometry Runner geometry Casing geometry	Speed diagrams Injector geometry Injector design Runner geometry	General information Basic equations Speed diagrams with: • basic runner dimensions • profile of runner blades • profile of distribution blades Power and efficiency Dimensioning of casing and runner

TABLE 2

Detailed Design		
Michell-Banki Turbines	**Pelton Turbines**	**Axial-flow Turbines**
• Injector design and calculation • Injector shaft and guide vanes design • Runner design and calculation • Shaft design and calculation • Bearing design and calculation • Regulating mechanism design	• Injector design and calculation • Runner design and calculation • Shaft design and calculation • Bearing support design • Regulating mechanism design • Casing and base structural design	• General aspects • Casing wall thickness calculation • Regulating blades stress and calculation • Runner blades stress calculation a) Determ. of forces b) Determ. of stresses • Turbine shaft design • Bearing selection • Turbine inertia moment

It would not be practical to describe in more detail the contents of the chapters as indicated in tables 1 and 2. However, the data given are sufficient to allow the calculation of a numerical example for each type of turbine mentioned above. These examples refer to:

- a 200 kW Michell-Banki Turbine
- a 500 kW Pelton Turbine
- a 700 kW Axial-flow Turbine

A few typical drawings and diagrams referring to the above machines taken from the notes are presented as annex 1 as follows:

(a) Michell-Banki Turbine:	Drawings 1/34, 2/34, 3/34, 4/34, 5/34, 6/34, and 10/34. Fig. 15-1 (diagram).
(b) Pelton Turbine:	Drawings 2/18, 3/18, 4/18, 7/18, 10/18, and 13/18. Figs. 16 and 17 (diagrams).
(c) Axial-flow Turbine:	Drawings TT 01 01 and TT 06 01, Fig. 24 (diagram) Table No. 11 (dimensions).

C. Standardization

Standardization is one, if not the only, crucial factor affecting the future success of SHPs. Without standardization the costs of SHPs become prohibitive in most cases. The part of the notes relating to standardization is concentrated on the manufacturing side of the issue. It is addressed mainly to manufacturers who are usually reluctant to fully participate in standardization efforts. Individually designed and manufacturing units are more to their liking.

On the one hand, it is evident that some of the manufacturing considerations in the notes will help local manufacturers to produce some parts - simple parts initially - as will be seen further in the section dealing with manufacturing (Section D, below).

On the other hand, it would appear to those who have dealt in more detail with standardization that it would be essential to make a serious effort to reduce the number of "standard" units mentioned in the notes further.

Effectively, figure 15-1 (see annex I) taken from volume I indicates six "zones" for which six different runner diameters for the **Michell-Banki** turbines would be applicable. Runners of 20, 30, 40, 50, 60, and 70 cms diameter are proposed.

For the **Pelton** types, figs. 16 and 17 indicate eight different standardized sizes, whereby a further distinction is made between machines driving generators via belts or gears and direct drives for a speed of 600 rpm.

It is suggested that the drive via belts or gears should be selected as being the most adaptable.

Figure 24 indicates the number and range of application of standardized **Tubular turbines** within a power range of 100 to 500 kW. Eight different types are presented. Table 11, in which the basic dimensions of this type of turbine are given, is useful.

D. Manufacturing

The notes in volumes I, II, and III rightly point out the difficulties inherent to manufacturing if the necessary know-how and facilities are not available. They emphasize the necessity of reasonably well-equipped workshops being available. For instance, casting, welding and galvanizing, and surface treating facilities are not available everywhere.

Useful information on the three types of units is given, such as materials, standards, manufacturing equipment and procedures to be used etc. Comments are also made on packing, lubrication, and erecting.

The parts for which corrosion-resistant alloys are to be used are indicated.

Also covered is the question of laboratory and test facilities, whereby, for instance, the necessity of testing the quality of the available water is emphasized. A list of applicable standards is given.

Amusing, but also useful, are the remarks made under the heading:

"For a suitable installation, what not to do" !

E. Additional remarks

As pointed out in the foregoing, all of the OLADE turbine volumes include one practical example per turbine type. This is possibly their most important part, because the step-by-step approach ensures that effective help is given to determine the main dimensions of SHP turbine units. The above procedure should at least enable the project engineer of a SHP to check his own considerations. In addition, reference is made to useful manufacturing information. For example, the part relating to the calculation of runner blades for Axial-flow turbines (see Annex 2).

A collection of detailed drawings applicable to the above three types of turbine, some of which were already mentioned in section B is to be found at the end of the respective volume. For manufacturing purposes, these drawings will have to be suitably completed and adapted to the specific needs of the manufacturer. Samples of those "manufacturing" drawings included in annex 1 are:

(a) for the Michell-Banki turbines: Drawing 10/34

(b) for the Pelton turbines: Drawings 7/18 10/18 and 13/18

(c) for the Axial-flow turbines: Drawing TT 01/01

(very few "manufacturing" drawings are available for the Axial-flow type of machine).

II. TURBINE SPEED REGULATORS DESIGN

A. General remarks

Volumes IV, V and VI dealing with speed regulation represent a considerable effort in dealing with a subject that technically has great importance for operating SHPs. It is clear that in areas where experienced operation staff are scarce, it is all the more important that speed regulation is reliable. It should also be simple to operate and, if difficulties occur, remedies should be easy to apply. Under the above circumstances, the amount of information contained in the three volumes will nonetheless be helpful to those organizations dealing with the design, realization and operation of SHPs' speed regulation equipment.

In connection with the subject of regulation, the question may also be asked whether, for the relatively small cost of the regulation equipment as compared to the total cost of the plants, it would not be advisable - and more economical - in specific cases to purchase the item from one of several reliable manufactures of such equipment.

B. Design

The main types of speed regulation equipment commented upon in the three volumes are:

(a) Oleomechanical speed regulation (volume IV);

(b) Electric/electronic speed regulation with positive load control, (volume V);

(c) Electric/electronic speed regulation with load dissipation (volume VI).

Table 3 summarizes the information given in relation to the three types of regulating equipment

TABLE 3

Regulating Equipment		
Oleomechanical regulator	Electric/electronic regulator with positive load control	Electric/electronic regulator with load dissipation
• General notions • Functional design • Mechanical calculations and regulator design	• General description and types • Functional design • Mechanical control parts • Electronic parts	• General description • Functional design

All three volumes go into detail regarding the function and main characteristics of the regulators and their calculation and design. Some components of the regulators are examined in detail. Mathematical models are also presented and described.

C. Standardization

Standardization of a small, but adequate, number of regulators for the three turbine types considered earlier will simplify design, construction, installation(1) and operation; regulator standardization should, however, also take into account Francis turbines. Their specific application for a specific size and type of turbine and/or mode of operation is, however, somewhat unclear, probably on account of the wealth of details presented in the notes.

The three basic standardized components of the regulators are indicated as:

(a) The information processor, common to all standardized speed regulators;

(b) The electrical part, consisting of the power circuits or the electronic trigger circuits;

---

[1] Note: It is believed that in most cases oleomechanical regulation should be given preference for SHPs.

(c) The pilot and hydraulic servo-motors, which are highly dependent upon the type and power produced by the turbine sets.

In the case of regulation with load dissipation, part C of volume VI deals mainly with considerations relating to load resistances.

As already mentioned in the introduction to this chapter (Section A, General remarks), speed regulation and its standardization could be simplified by the users to facilitate the selection, design and operation of SHPs, according to their particular needs. The aim should be to have no more than four to five "standardized" regulating items of equipment per turbine type, as detailed in volumes I, II and III. This standardization may, however, only apply partially to the mechanical equipment transmitting the regulation impulses to the turbine.

D. Manufacturing

All three volumes (IV, V and VI) foresee the local fabrication of components such as tachometers, pilot valves, servo-motors, pumps, springs, pistons, consoles etc., apart from the electrical and electronic components. Although such fabrication may be possible in a few selected countries, the view has already been expressed that the equipment should be purchased as a unit from specialized firms. However, it is clear that, if standardization of only a few types of regulating equipment were made possible, one should investigate which of the components could be manufactured locally, with perhaps only one or two countries supplying the rest. Also, there may be some simple mechanical parts such as levers, valves and casings that would be suitable for local manufacture. However, one should make sure that the manufacture of such parts is economical.

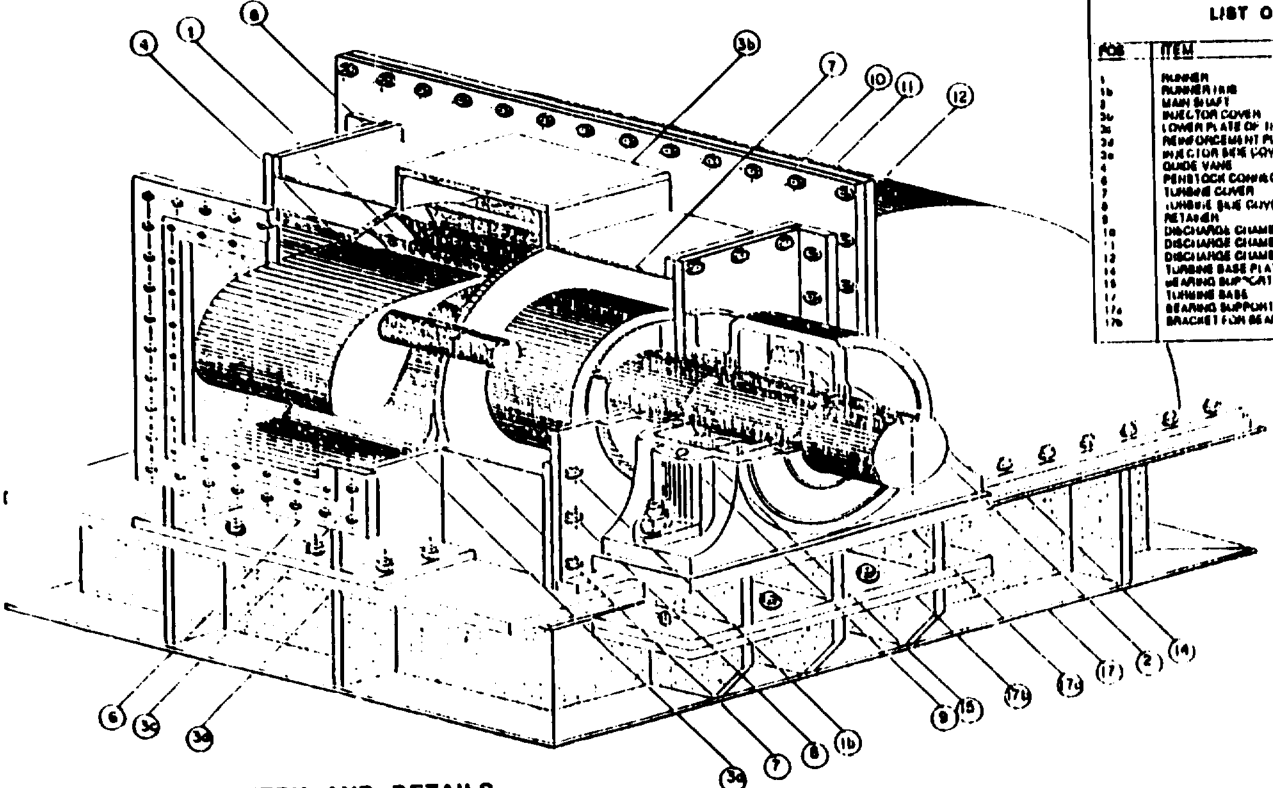
E. Additional remarks

For the first two types of regulators (volumes IV and V) an example as to how a speed regulator should be designed and calculated is to be found in the annexure of the corresponding volume.

In the respective appendices, detailed drawings will also be found, including simulation programs and computer calculations programs.

Annex 1

TECHNICAL DRAWINGS FIGURES AND TABLES



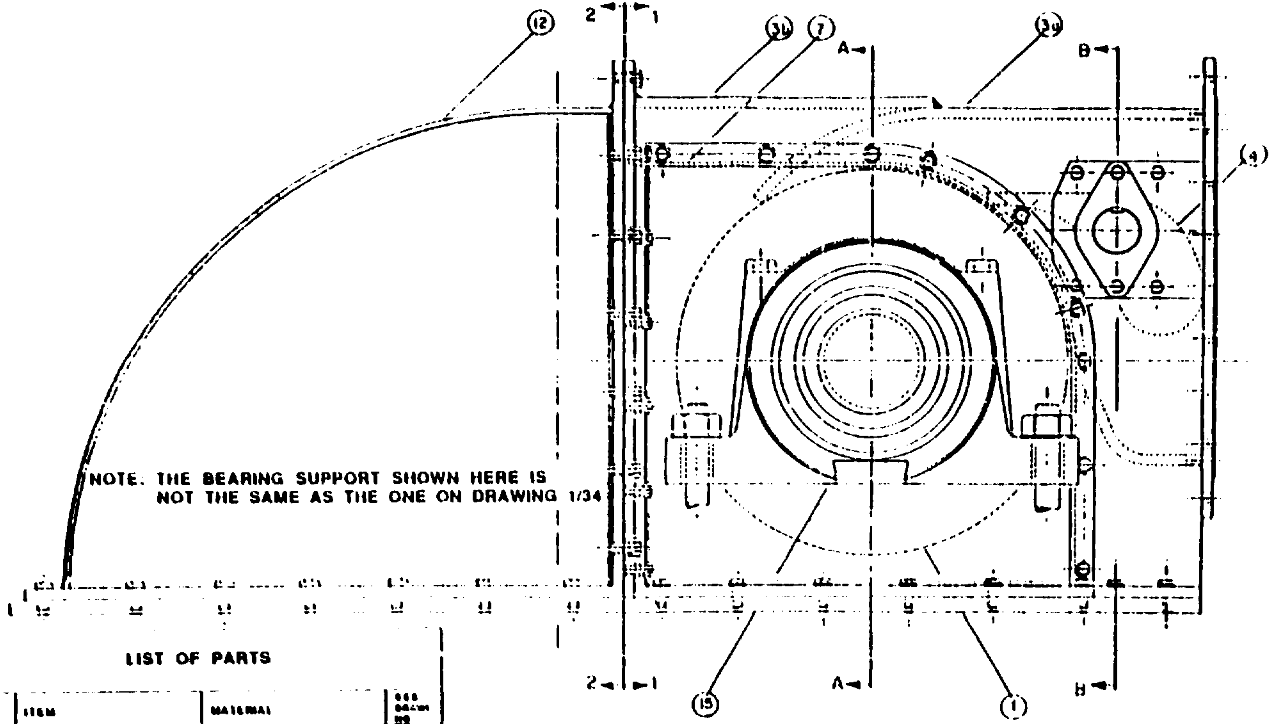
LIST OF PARTS

POS	ITEM
1	RUNNER
1b	RUNNER HUB
2	MAIN SHAFT
3b	INJECTOR COVER
3c	LOWER PLATE OF THE INTAKE CHAMBER
3d	REINFORCEMENT PLATE FOR THE INTAKE CHAMBER
3e	INJECTOR SIDE COVER
4	GUIDE VANE
6	PENSTOCK CONNECTING FLANGE
7	TURBINE COVER
8	TURBINE SIDE COVERS
9	RETAINER
10	DISCHARGE CHAMBER CONNECTING FLANGE
11	DISCHARGE CHAMBER FLANGE
12	DISCHARGE CHAMBER
14	TURBINE BASE PLATE
15	BEARING SUPPORT
17	TURBINE BASE
17a	BEARING SUPPORT BASE
17b	BRACKET FOR BEARING SUPPORT BASE

ISOMETRY AND DETAILS

MICHELL-BANKI TURBINE

VOLUME I - DRAWING No. 1/34



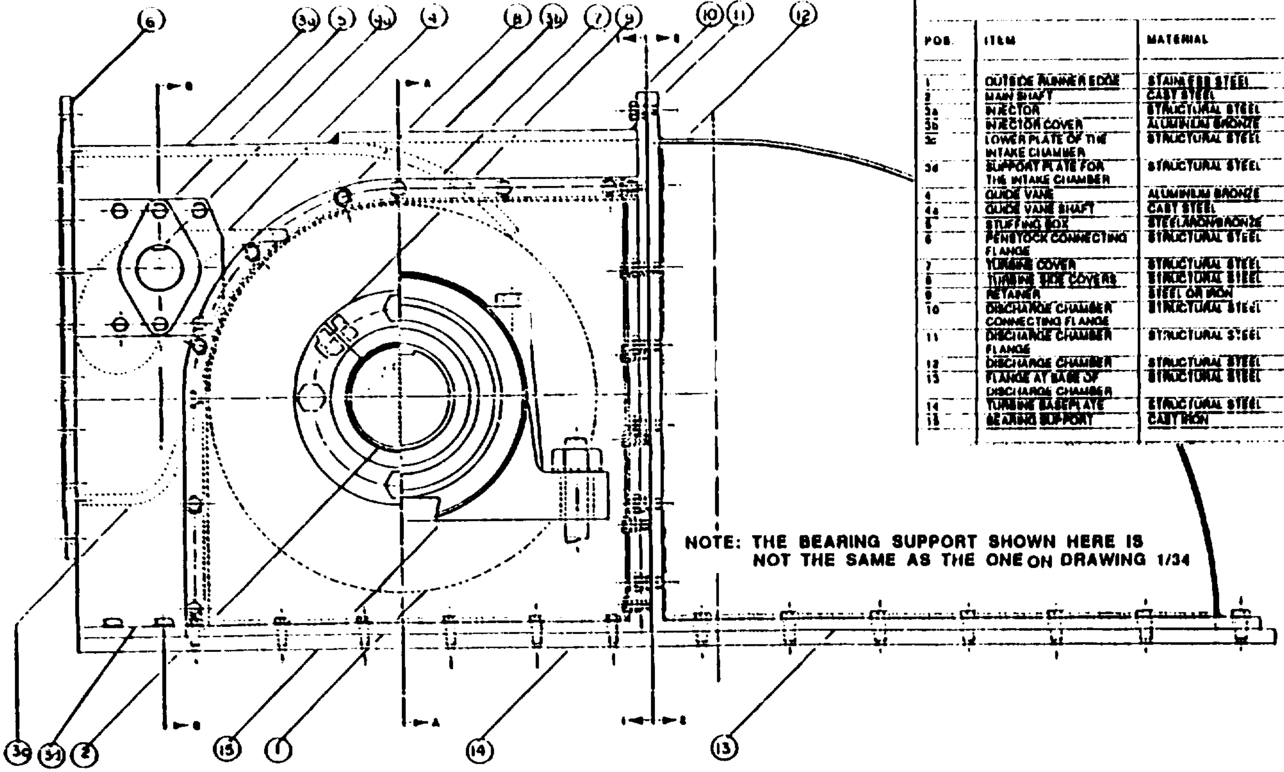
NOTE: THE BEARING SUPPORT SHOWN HERE IS NOT THE SAME AS THE ONE ON DRAWING 1/34

LIST OF PARTS

POS	ITEM	MATERIAL	SEE DRAWING No
1	RUNNER EDGE	STAINLESS STEEL	8
3a	EJECTOR	STRUCTURAL STEEL	16
3b	EJECTOR COVER	STRUCTURAL STEEL	16
4	GUIDE VANE	ALUMINIUM BRONZE	13
7	TURBINE COVER	STRUCTURAL STEEL	23
12	DISCHARGE CHAMBER	STRUCTURAL STEEL	30
15	BEARING SUPPORT	CAST IRON	

FINAL TURBINE ASSEMBLY
LEFT VIEW

VOLUME I - DRAWING No. 2/34



LIST OF PARTS

POS.	ITEM	MATERIAL	SEE DRAWING
1	OUTSIDE RUNNER EDGE	STAINLESS STEEL	6
2	MAIN SHAFT	CAST STEEL	11
3a	INJECTOR	STRUCTURAL STEEL	16
3b	INJECTOR COVER	ALUMINIUM BRONZE	17
3c	LOWER PLATE OF THE INTAKE CHAMBER	STRUCTURAL STEEL	18
3d	SUPPORT PLATE FOR THE INTAKE CHAMBER	STRUCTURAL STEEL	18
4	GUIDE VANE	ALUMINIUM BRONZE	13
4a	GUIDE VANE SHAFT	CAST STEEL	13
5	STUFFING BOX	STEEL/IRON/BRONZE	15
6	PENSTOCK CONNECTING FLANGE	STRUCTURAL STEEL	21
7	TURBINE COVER	STRUCTURAL STEEL	22
8	TURBINE SIDE COVERS	STRUCTURAL STEEL	24
9	RETAINER	STEEL OR IRON	25
10	DISCHARGE CHAMBER CONNECTING FLANGE	STRUCTURAL STEEL	26
11	DISCHARGE CHAMBER FLANGE	STRUCTURAL STEEL	27
12	DISCHARGE CHAMBER	STRUCTURAL STEEL	29
13	FLANGE AT BASE OF DISCHARGE CHAMBER	STRUCTURAL STEEL	28
14	TURBINE BASEPLATE	STRUCTURAL STEEL	31
15	BEARING SUPPORT	CAST IRON	

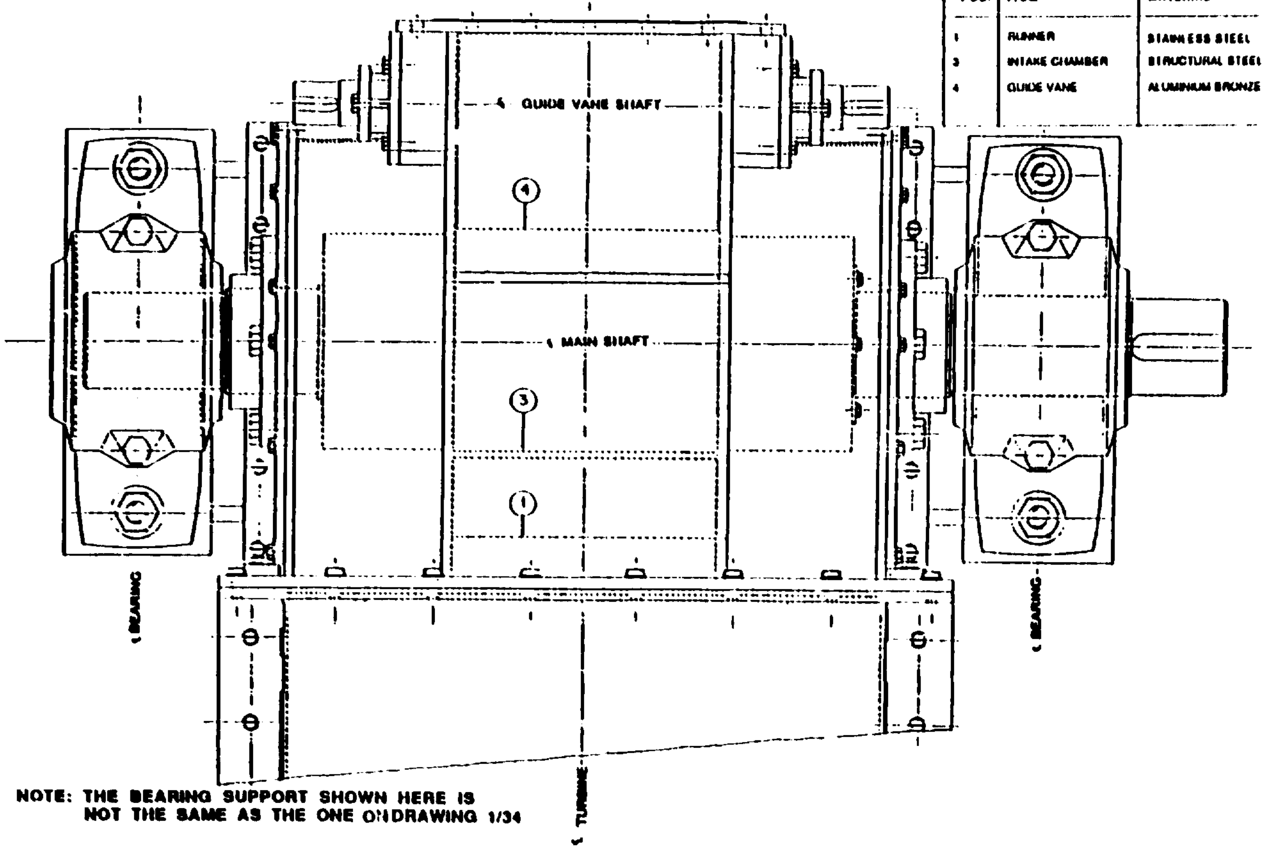
NOTE: THE BEARING SUPPORT SHOWN HERE IS
NOT THE SAME AS THE ONE ON DRAWING 1/34

FINAL TURBINE ASSEMBLY
RIGHT VIEW

VOLUME I - DRAWING No. 3/34

LIST OF PARTS

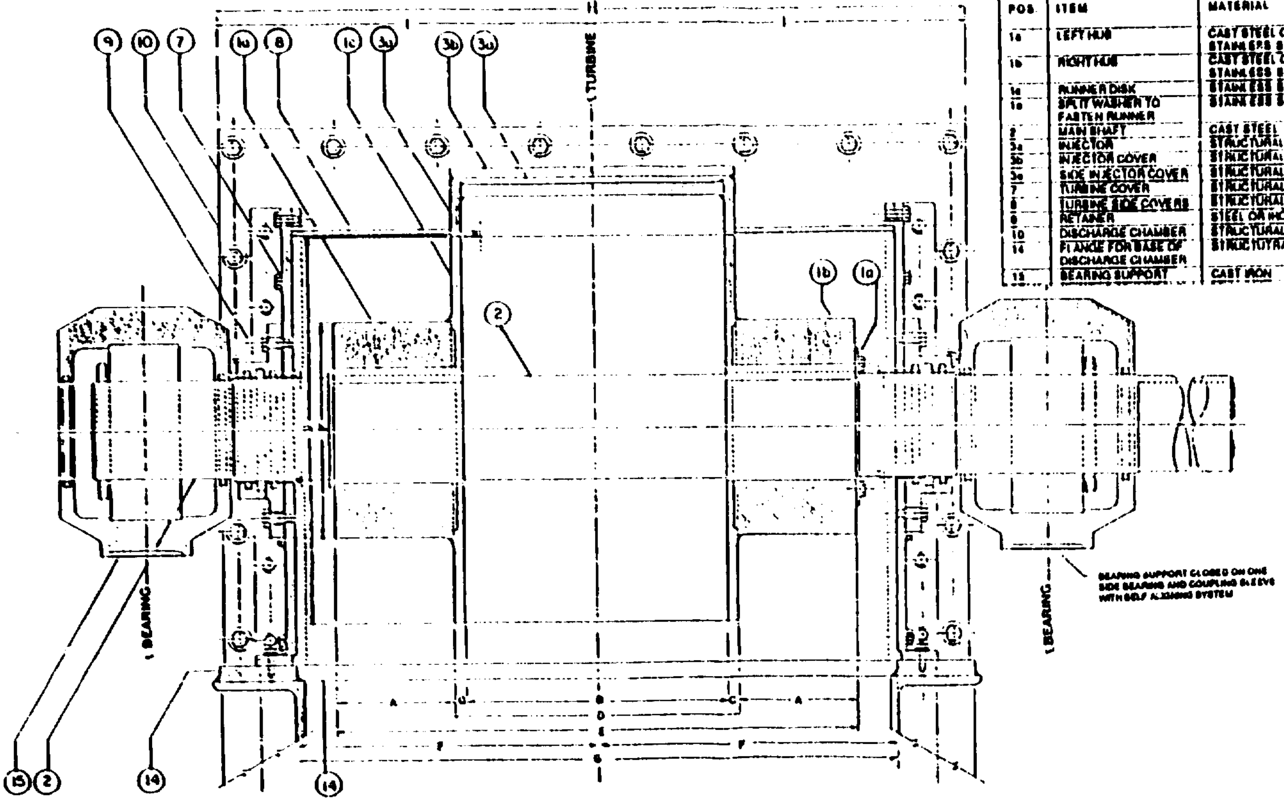
POS.	ITEM	MATERIAL	SEE DRAWING
1	RUNNER	STAINLESS STEEL	8
3	INTAKE CHAMBER	STRUCTURAL STEEL	12
4	GUIDE VANE	ALUMINIUM BRONZE	13



NOTE: THE BEARING SUPPORT SHOWN HERE IS NOT THE SAME AS THE ONE ON DRAWING 1/34

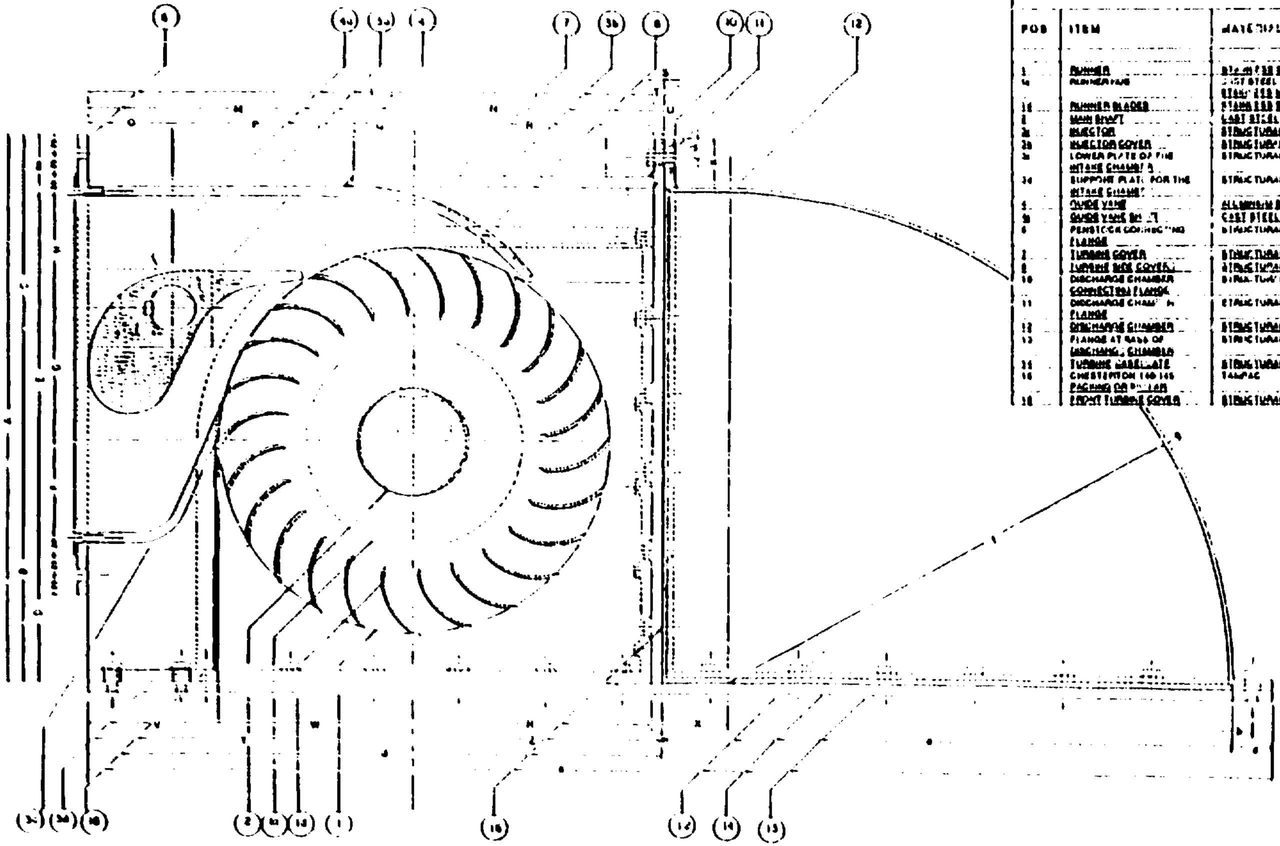
FINAL TURBINE ASSEMBLY
TOP VIEW

VOLUME I - DRAWING No. 4/34



LIST OF PARTS			
POS.	ITEM	MATERIAL	SEE DRAWING
1a	LEFT HUB	CAST STEEL OR STAINLESS STEEL	10
1b	RIGHT HUB	CAST STEEL OR STAINLESS STEEL	10
1c	RUNNER DISK	STAINLESS STEEL	9
1d	SPLIT WASHER TO FASTEN RUNNER	STAINLESS STEEL	10
2	MAIN SHAFT	CAST STEEL	11
3a	INJECTOR	STRUCTURAL STEEL	16
3b	INJECTOR COVER	STRUCTURAL STEEL	16
3c	SIDE INJECTOR COVER	STRUCTURAL STEEL	17
7	TURBINE COVER	STRUCTURAL STEEL	23
8	TURBINE SIDE COVERS	STRUCTURAL STEEL	24
9	RETAINER	STEEL OR IRON	25
10	DISCHARGE CHAMBER	STRUCTURAL STEEL	26
14	FLANGE FOR BASE OF DISCHARGE CHAMBER	STRUCTURAL STEEL	28
15	BEARING SUPPORT	CAST IRON	

CROSS-SECTION "A-A" - VIEW OF THE RUNNER, MAIN SHAFT, RETAINER AND CASING

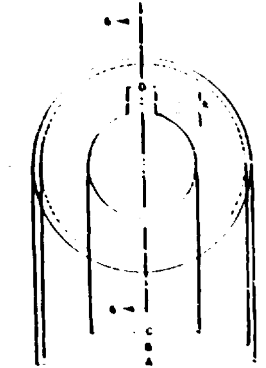


LIST OF PARTS

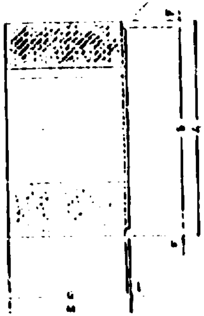
POS	ITEM	MATERIAL	SEE DRAWING
1	RUNNER	STAINLESS STEEL	8
1a	RUNNER HUB	CAST STEEL OR STAINLESS STEEL	10
1b	RUNNER BLADES	STAINLESS STEEL	9
2	MAIN SHAFT	CAST STEEL	11
3a	INJECTOR	STRUCTURAL STEEL	16
3b	INJECTOR COVER	STRUCTURAL STEEL	16
3c	LOWER PLATE OF THE INTAKE CHAMBER	STRUCTURAL STEEL	19
3d	SUPPORT PLATE FOR THE INTAKE CHAMBER	STRUCTURAL STEEL	20
5	GUIDE VANE	ALUMINIUM BRONZE	13
5a	GUIDE VANE SHAFT	CAST STEEL	13
6	PENSTOCK CONNECTING FLANGE	STRUCTURAL STEEL	21
7	TURBINE COVER	STRUCTURAL STEEL	23
8	TURBINE SIDE COVERS	STRUCTURAL STEEL	24
10	DISCHARGE CHAMBER CONNECTING FLANGE	STRUCTURAL STEEL	26
11	DISCHARGE CHAMBER FLANGE	STRUCTURAL STEEL	27
12	DISCHARGE CHAMBER	STRUCTURAL STEEL	28
13	FLANGE AT BASE OF DISCHARGE CHAMBER	STRUCTURAL STEEL	29
15	TURBINE BASEPLATE	STRUCTURAL STEEL	31
16	CHESTERTON 160 165 PACKING OR [illegible]	TAMPAC	
18	FRONT TURBINE COVER	STRUCTURAL STEEL	19

FINAL TURBINE ASSEMBLY
LONGITUDINAL SECTION

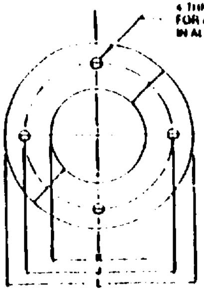
VOLUME I - DRAWING No. 6/34



PART No. 1a - LEFT HUB
MATERIAL: CAST STEEL OR
STAINLESS STEEL

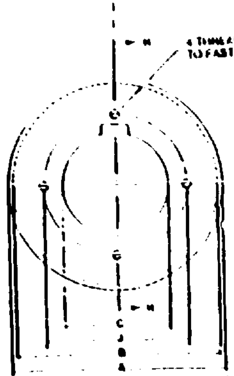


CROSS SECTION "G G"

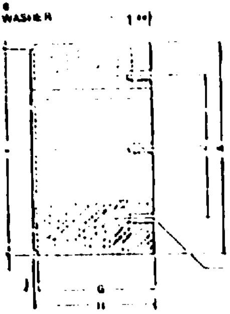


PART No. 1e - SPLIT WASHER TO
FASTEN THE RUNNER
TO THE MAIN SHAFT
MATERIAL: STAINLESS STEEL

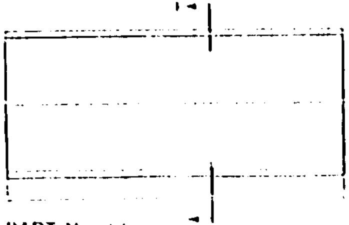
NOTE IN ALL CASES THE WASHER
WILL BE 5 mm. THICK



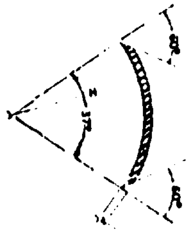
PART No. 1b - RIGHT HUB
MATERIAL: CAST STEEL OR
STAINLESS STEEL



CROSS SECTION "H H"



PART No. 1d
- VIEW OF THE RUNNER BLADE
MATERIAL: STAINLESS STEEL



CROSS SECTION "I I"

NOTE ALL THE RUNNERS WILL HAVE
24 BLADES NO MATTER WHAT
THE RUNNER DIAMETER

RUNNER COMPONENTS

VOLUME I - DRAWING No. 10/34

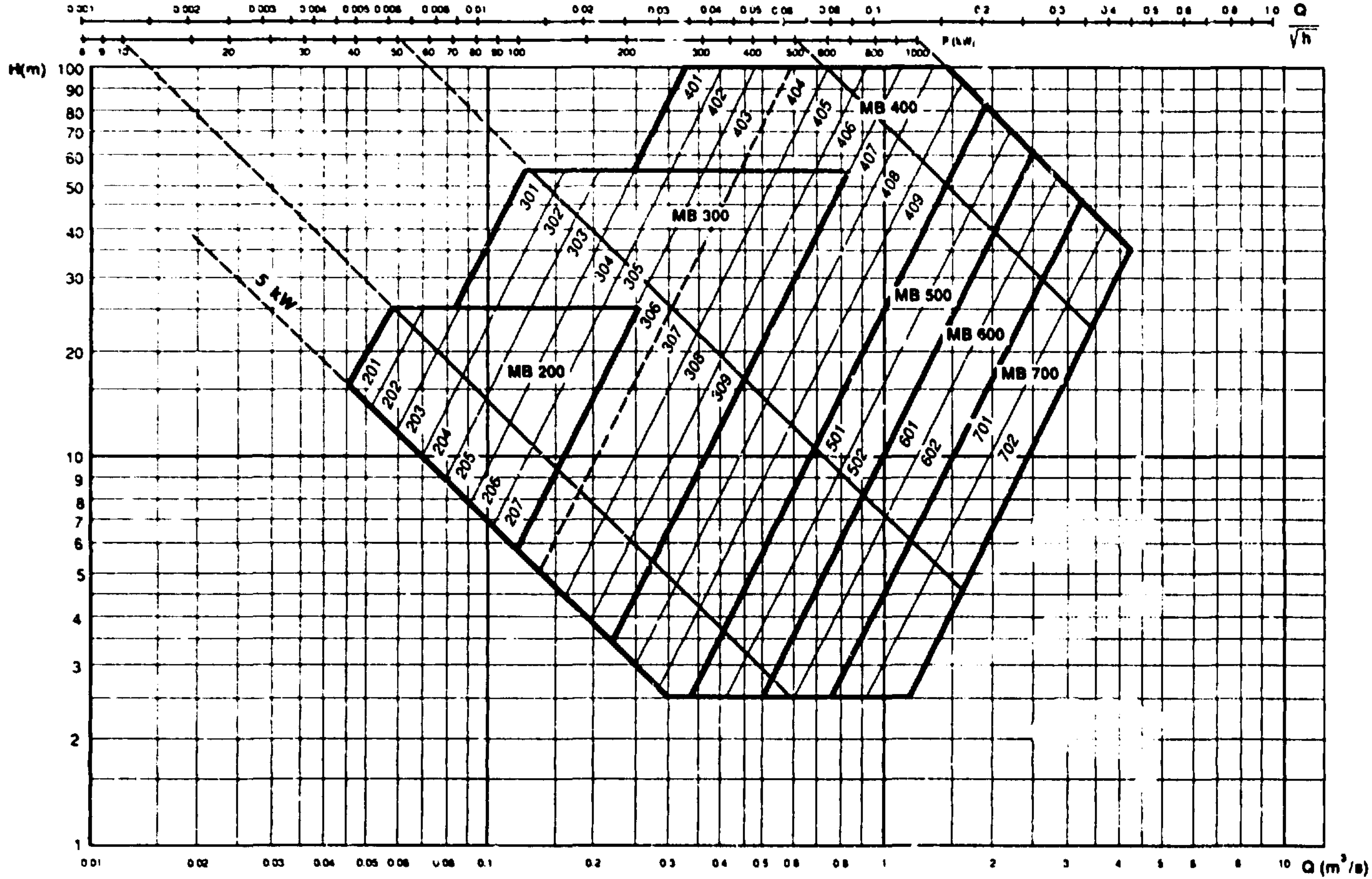
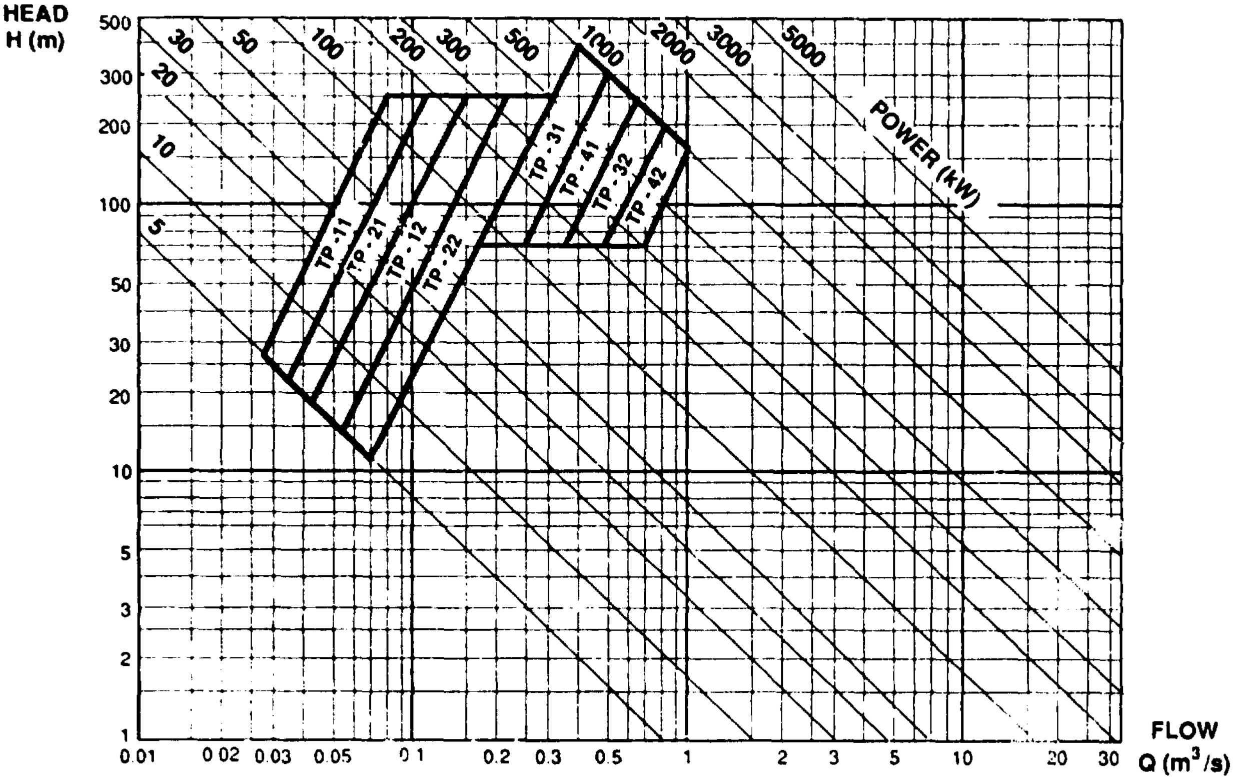
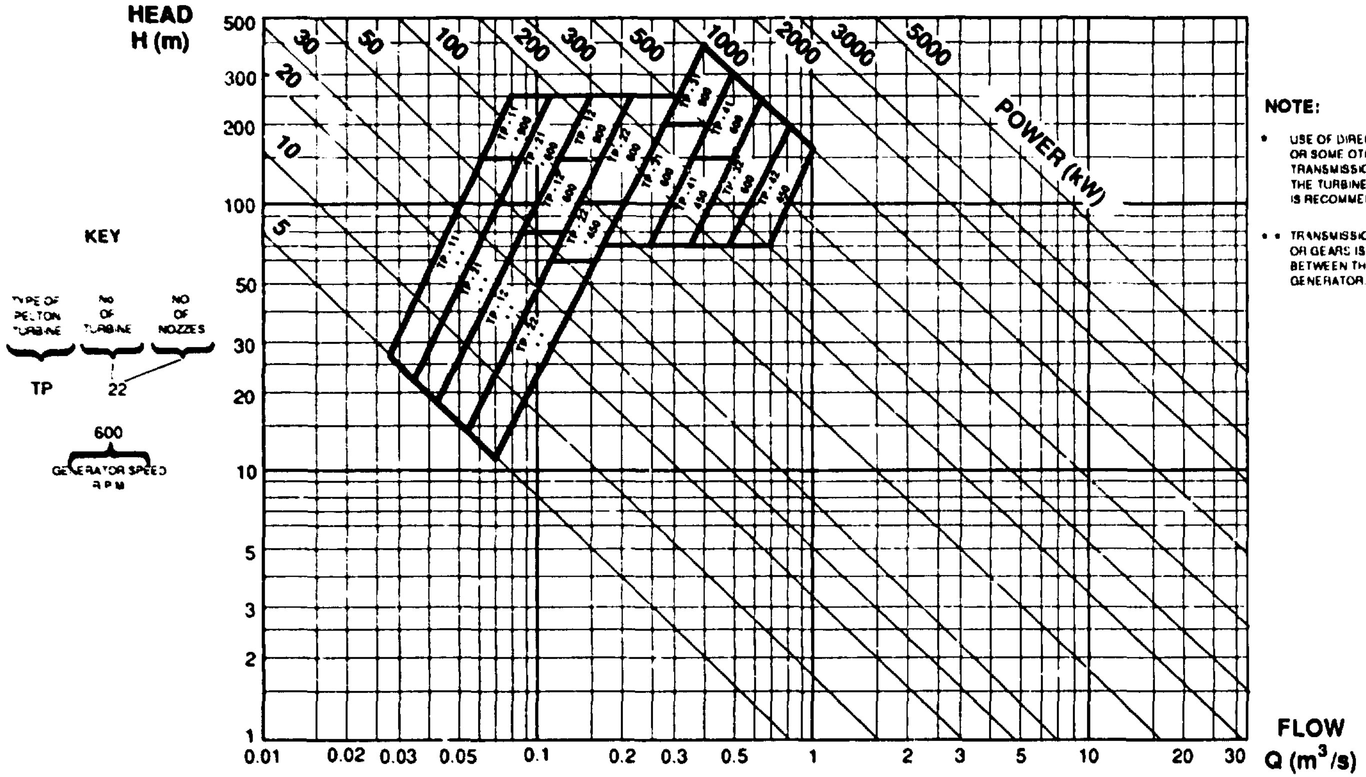


FIGURE 15 - 1
STANDARDIZATION OF MICHELL BANKI TURBINES USING HYDRAULIC AND MECHANICAL CRITERIA



EXAMPLE OF PELTON TURBINE STANDARDIZATION FOR TRANSMISSION BY BELTS OR GEARS

Figure No. 16

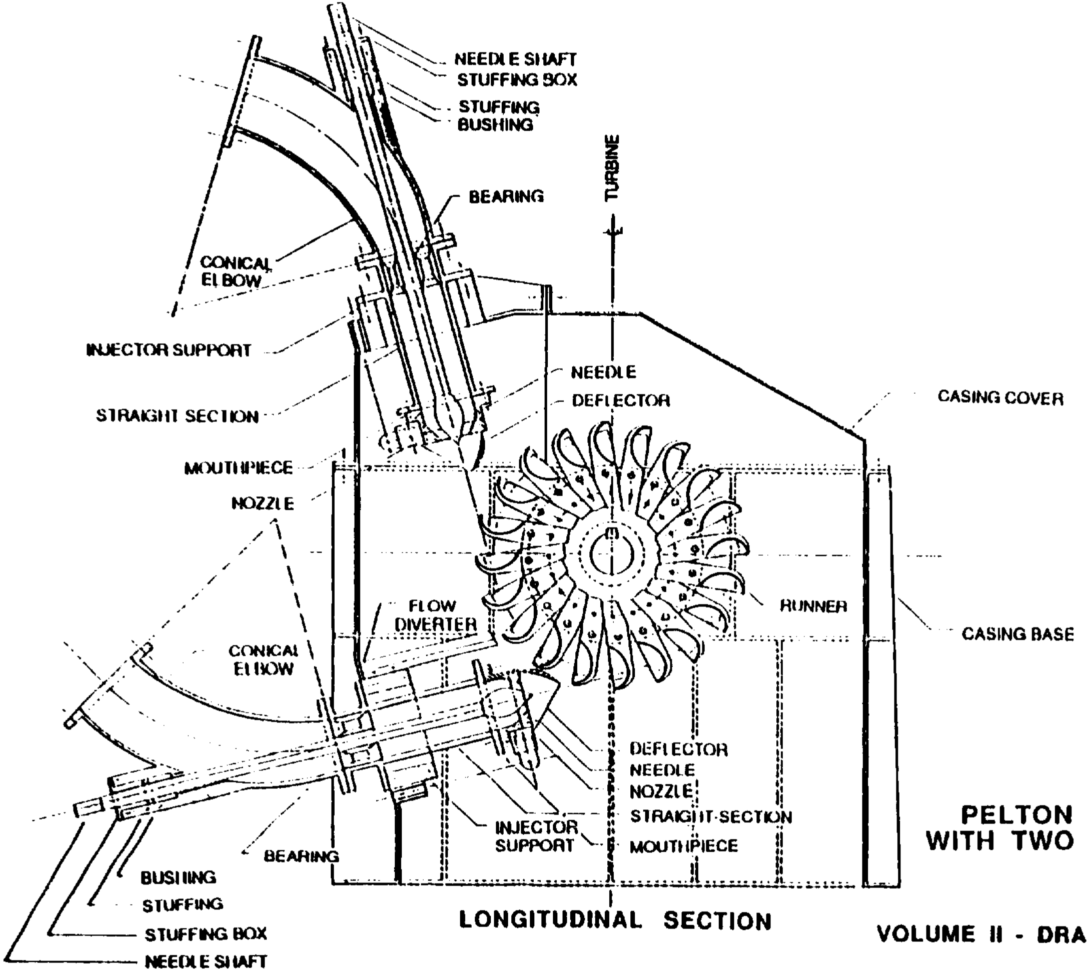


NOTE:

- * USE OF DIRECT COUPLING OR SOME OTHER KIND OF TRANSMISSION BETWEEN THE TURBINE AND GENERATOR IS RECOMMENDED
- * * TRANSMISSION BY BELTS OR GEARS IS RECOMMENDED BETWEEN THE TURBINE AND GENERATOR

EXAMPLE OF PELTON TURBINE STANDARDIZATION FOR DIRECT COUPLING

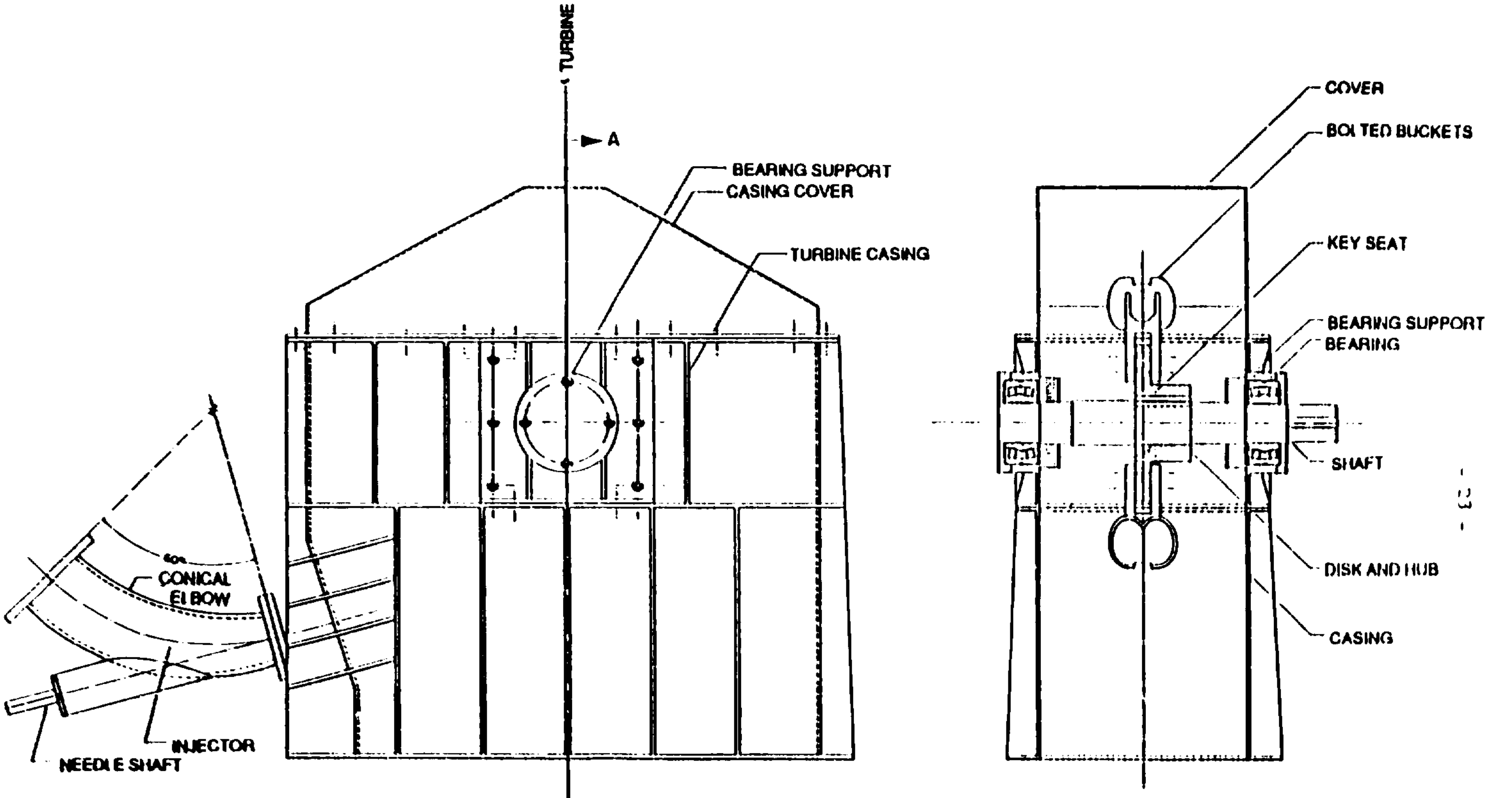
Figure No. 17



LONGITUDINAL SECTION

PELTON TURBINE WITH TWO INJECTORS

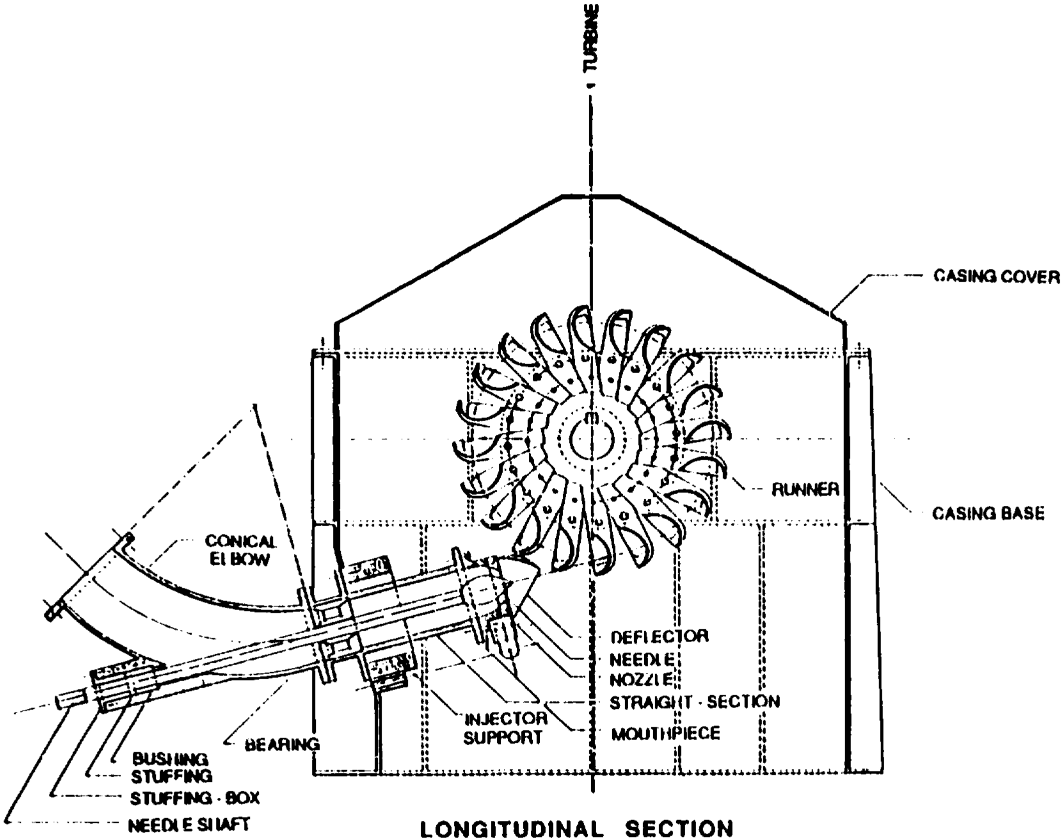
VOLUME II - DRAWING No. 2/18



CROSS - SECTION A - A

SINGLE INJECTOR TURBINE

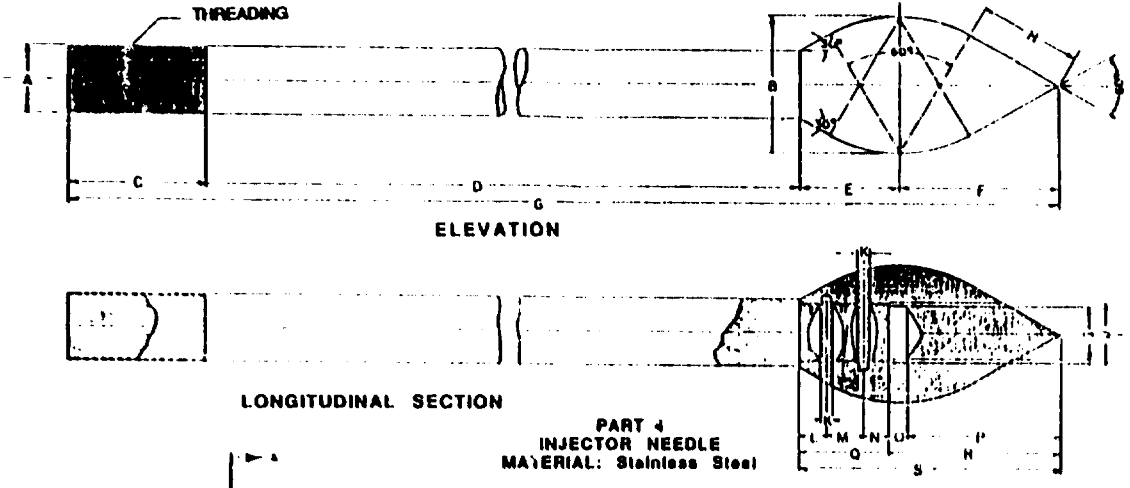
VOLUME II - DRAWING No. 3/18



LONGITUDINAL SECTION

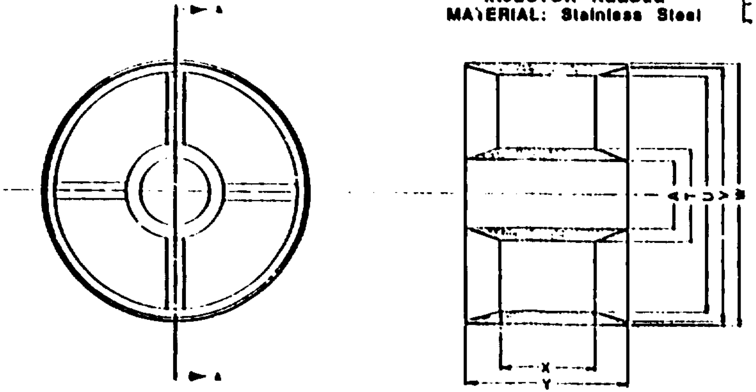
SINGLE - INJECTOR TURBINE

VOLUME II - DRAWING No. 4/18



PART 4
INJECTOR NEEDLE
MATERIAL: Stainless Steel

	TABLE OF DIMENSIONS (mm)					
	TURBINE TYPE					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
A	46	56	96	110	110	130
B	[illegible]	[illegible]	136	[illegible]	151	[illegible]
C	[illegible]	100	[illegible]	[illegible]	[illegible]	[illegible]
D	1040	1270	2140	2130	2140	2130
E	57	70	[illegible]	[illegible]	131	[illegible]
F	[illegible]	100	[illegible]	185	[illegible]	248
G	[illegible]	[illegible]	[illegible]	2013	[illegible]	[illegible]
H	[illegible]	74	[illegible]	157	140	155
I	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
J	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
K	8	8	12	16	20	20
L	19	20	24	28	32	36
M	[illegible]	[illegible]	47	[illegible]	[illegible]	[illegible]
N	16	16	[illegible]	[illegible]	36	34
O	11	[illegible]	36	[illegible]	117	[illegible]
P	64	[illegible]	170	[illegible]	170	[illegible]
Q	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
R	[illegible]	110	[illegible]	[illegible]	[illegible]	[illegible]
S	140	175	[illegible]	[illegible]	[illegible]	[illegible]
T	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
U	[illegible]	147	[illegible]	[illegible]	[illegible]	[illegible]
V	[illegible]	165	[illegible]	[illegible]	[illegible]	[illegible]
W	[illegible]	177	[illegible]	341	[illegible]	341
X	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Y	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

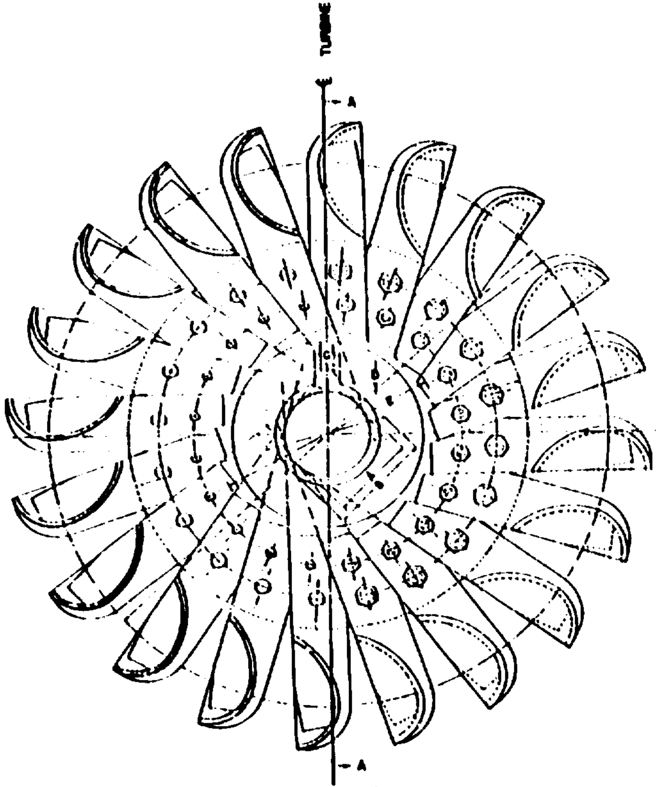


FRONT VIEW

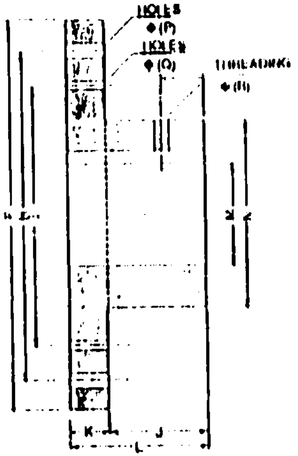
SECTION A - A

PART 5
NEEDLE BUSHING
MATERIAL: Bronze

VOLUME II - DRAWING No. 7/18



ELEVATION
SECTION VIEW



CROSS - SECTION A - A

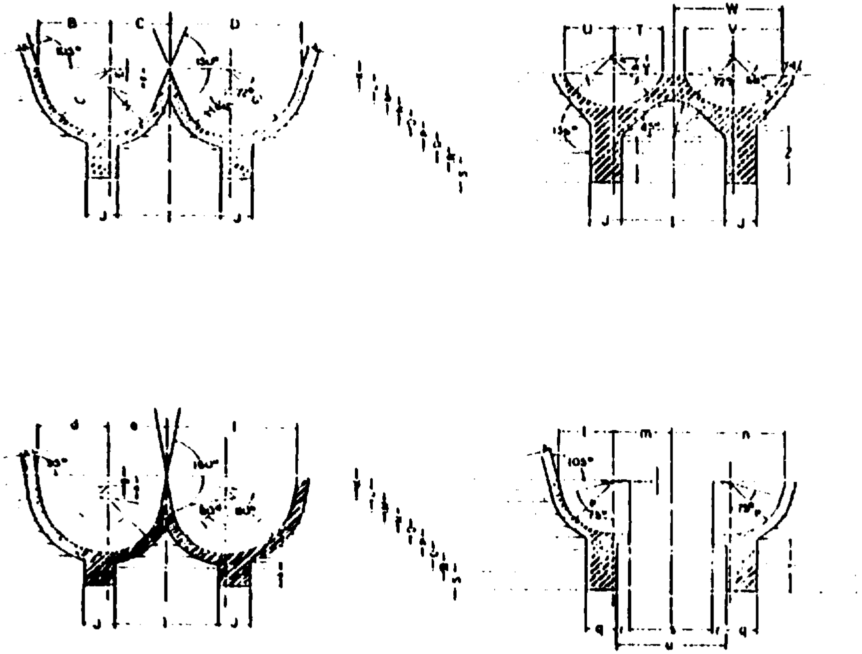
TABLE OF DIMENSIONS (mm)

TURBINE TYPE

[illegible]

RUNNER WITH BOLTED BUCKETS

VOLUME II - DRAWING No. 10/18

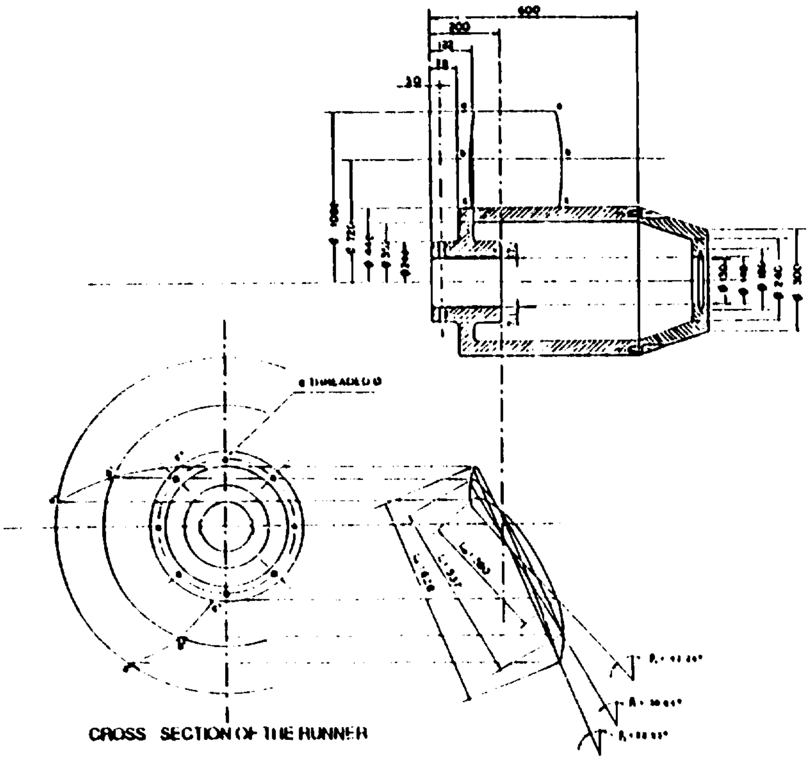


CROSS - SECTIONS OF BOLTED BUCKETS

TABLE OF DIMENSIONS (mm)	TURBINE TYPE					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
A	60	60	60	60		
B	410	455	410	455		
C	340	440	340	440		
D	760	885	760	885		
E	10	20	10	20		
F	120	180	120	180		
G	300	410	300	410		
H	330	360	330	360		
I	690	820	690	820		
J	180	300	180	300		
K	60	75	60	75		
L	[illegible]	[illegible]	[illegible]	[illegible]		
M	[illegible]	[illegible]	[illegible]	[illegible]		
N	[illegible]	[illegible]	[illegible]	[illegible]		
O	[illegible]	[illegible]	[illegible]	[illegible]		
P	[illegible]	[illegible]	[illegible]	[illegible]		
Q	[illegible]	[illegible]	[illegible]	[illegible]		
R	[illegible]	[illegible]	[illegible]	[illegible]		
S	110	120	110	120		
T	[illegible]	[illegible]	[illegible]	[illegible]		
U	[illegible]	[illegible]	[illegible]	[illegible]		
V	[illegible]	[illegible]	[illegible]	[illegible]		
W	[illegible]	[illegible]	[illegible]	[illegible]		
X	310	[illegible]	310	[illegible]		
Y	[illegible]	[illegible]	[illegible]	[illegible]		
Z	[illegible]	[illegible]	[illegible]	[illegible]		
a	[illegible]	[illegible]	[illegible]	[illegible]		
b	90	100	90	100		
c	110	120	110	120		
d	420	500	420	500		
e	340	410	340	410		
f	[illegible]	815	[illegible]	815		
g	60	70	60	70		
h	[illegible]	370	[illegible]	370		
i	300	410	300	410		
j	310	330	310	310		
k	[illegible]	[illegible]	[illegible]	[illegible]		
l	[illegible]	[illegible]	[illegible]	[illegible]		
m	[illegible]	[illegible]	[illegible]	[illegible]		
n	[illegible]	[illegible]	[illegible]	[illegible]		
o	[illegible]	[illegible]	[illegible]	[illegible]		
p	[illegible]	[illegible]	[illegible]	[illegible]		
q	[illegible]	[illegible]	[illegible]	[illegible]		
r	[illegible]	[illegible]	[illegible]	[illegible]		
s	75	65	75	65		
t	[illegible]	[illegible]	[illegible]	[illegible]		
u	[illegible]	[illegible]	[illegible]	[illegible]		

VOLUME II - DRAWING No. 13/18

AXIAL SECTION OF THE RUNNER

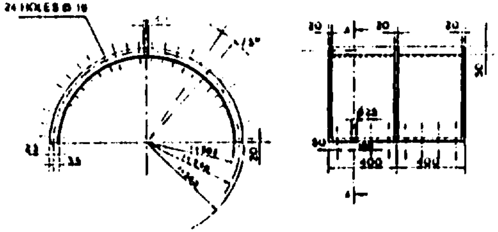


CROSS SECTION OF THE RUNNER

CYLINDRICAL BLADE DEVELOPMENT

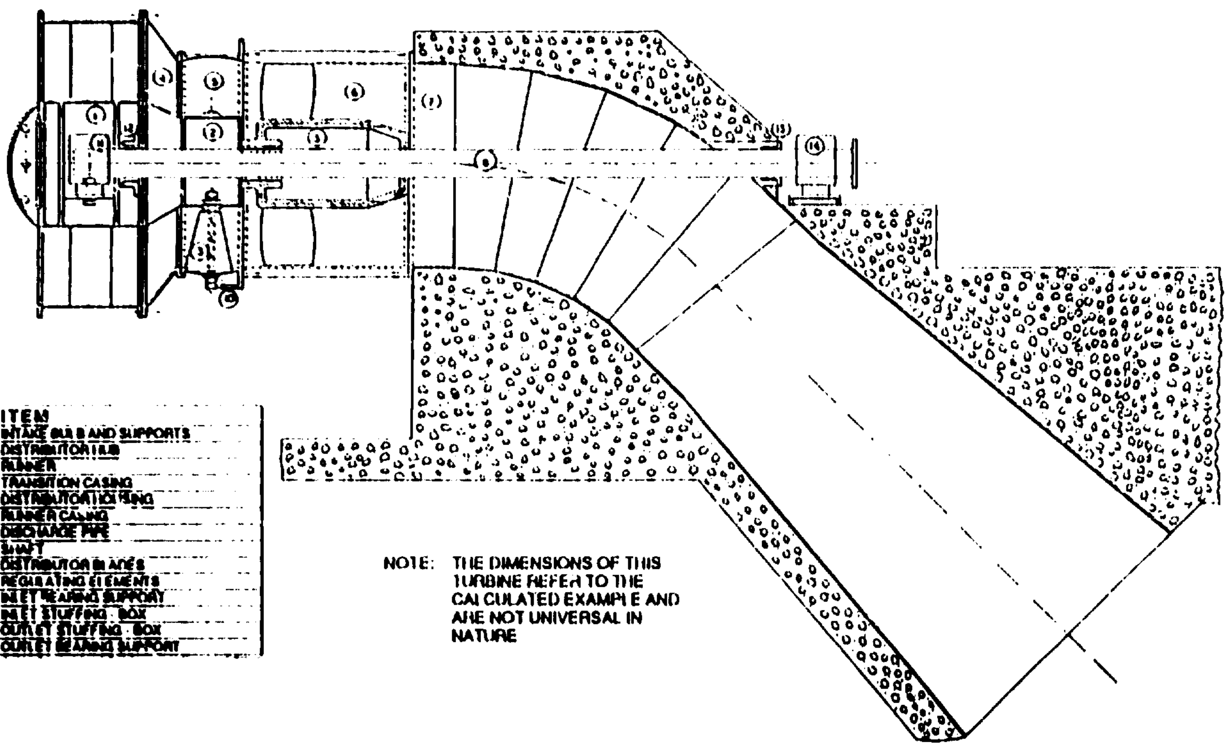
RUNNER CASING

CROSS - SECTION A - A



RUNNER AND RUNNER CASING
AXIAL - FLOW (TUBULAR) TURBINES

VOLUME III - DRAWING No. TT - 01 - 01



N°	ITEM
1	INTAKE BULB AND SUPPORTS
2	DISTRIBUTOR HUB
3	RUNNER
4	TRANSITION CASING
5	DISTRIBUTOR HOUSING
6	RUNNER CASING
7	DISCHARGE PIPE
8	SHAFT
9	DISTRIBUTOR BLADES
10	REGULATING ELEMENTS
11	INLET BEARING SUPPORT
12	INLET STUFFING - BOX
13	OUTLET STUFFING - BOX
14	OUTLET BEARING SUPPORT

NOTE: THE DIMENSIONS OF THIS TURBINE REFER TO THE CALCULATED EXAMPLE AND ARE NOT UNIVERSAL IN NATURE

LONGITUDINAL SECTION OF AN AXIAL FLOW TURBINE INSTALLATION

VOLUME III - DRAWING No. TT - 06 - 01

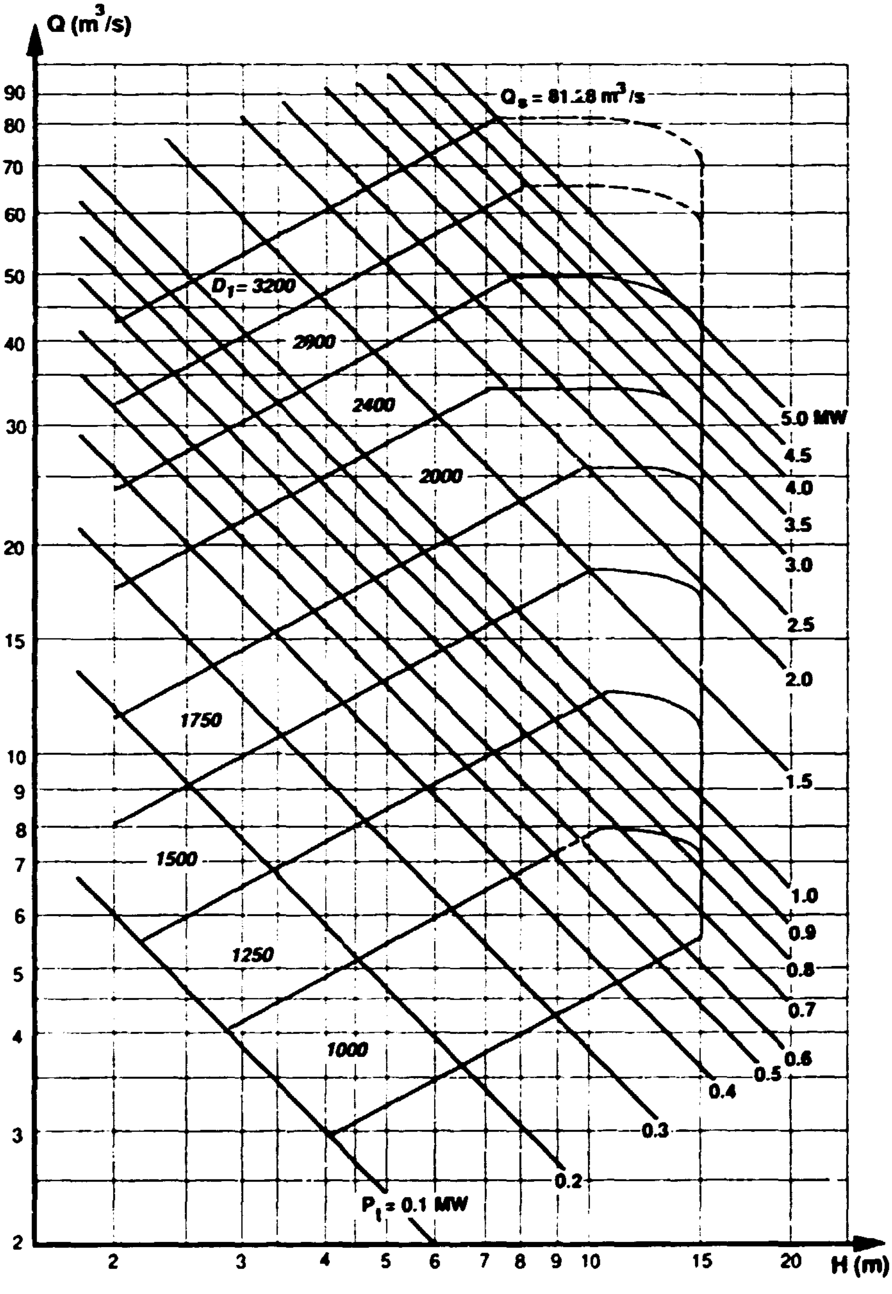


Fig. No. 24. Diagram for the Selection of Tubular Turbines

TABLE No. 11

BASIC DIMENSIONS OF STANDARDIZED AXIAL FLOW TURBINES

D_1 (mm) ITEM	**1000**	**1250**	**1500**	**1750**	**2000**	**2400**	**2800**	**3200**
Intake Diam.	1000	1250	1500	1750	2000	2400	2800	3200
Intake Length	2000	2500	3000	3500	4000	4800	5600	6400
Distrib. Length	1700	2130	2550	2980	3400	4080	4760	5440
Runner Length	600	750	900	1050	1200	1440	1680	1920
Discharge Length	5000	6250	7000	8750	10000	12000	14000	16000
Discharge Depth	3000	3750	4500	5200	6000	7200	8400	9400
Shaft Length	3000	3750	4500	5200	6000	7200	8400	9400
Casing Length	5800	7250	8700	10150	11600	13920	16240	18560

ANNEX 2

Selection of the Profile of the Runner Blades
(Drawing No. TT-00-01)

[*Example (Volume III, page 59 No. 2.4 , English version)*]

According to Table No. 1, *) the number of blades should be comprised between 3 and 4. Four blades have been choosen because the turbine must work with a nominal head of 14 m. For cast blades, Nos. 622, 623, 624 and 625 profiles of the Gottingen series are convenient. For purposes herein, No. 624, of a medium thickness, will be chosen; its characteristics are as follows:

$$y_{max} = 16\% \ L$$
$$\varepsilon = 0.012 + 0.052 \ (y_{max} \ / \ L) \qquad (42)$$

Initial value of $C_L = 2 \pi \sin (\alpha + \delta')$, where $\delta' = \beta_c - \beta_o$.

For the middle section and the periphery, the profile has been made 60% thinner and the hub profile 80% thinner.

Dimensions of the Gottingen 624 Profile (%L)

X	0	5	10	15	20	30	40	50	60	80	95	100
Y_o	4.00	10.40	12.85	14.35	15.30	16.00	15.40	14.05	12.00	6.60	2.00	0.50
Y_u	4.00	0.95	0.40	0.15	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
$\bar{Y}$	4.00	5.68	6.63	7.25	7.68	8.00	7.70	7.03	6.00	3.30	1.00	0.20

The values for $\bar{Y}$ represent the ordinates of the middle line of the profile. Joining the inicial and end points of the middle line yields the profile chord which forms an angle Θ with the axis of the abscissa. Likewise, by joining the middle point and the end point of the middle line, the angle Θ' is formed between the shaft and the probable direction of the zero axis. Finally, α' the angle , formed between the tangent of the discharge and the shaft of the abscissa, may be calculated using the ordinate for the point located at 95% L.

Thus:

$$\Theta = \beta_c - \beta_c = \text{arc tan } (4.00/100) = 2.29^\circ$$

$$\Theta' = \beta_c - \beta_c = \text{arc tan } (7.03/50) = 8.00^\circ$$

$$\alpha' = \beta_e - \beta_2 = \text{arc tan } (1/5) = 11.31^\circ$$

Once the angles α and δ' are known, it is possible to determine the value of output Z in each runner section. To do this, the following procedure should be adopted:

- Preliminary estimate of the value for C_L.
- Evaluation of the coefficient ε by replacing (y_{max} / L)
- Evaluation of the factor K_λ on the basis of the values for ε and β_m.
- Calculation of the product $(\sigma \bullet K_L)$ on the basis of Formula No. 27
- Evaluation of the factors of the product $(\sigma \bullet K_L)$ given by Figure No. 11 for each value of βo.
- Obtention of the final value for C_L with the value for $(\sigma \bullet K_L)$ replaced in Formula 27.
- Calculation of the value for the C_t coefficient with Formula 38.
- Verification of the value for σ with Formula 37.
- Verification of the value for ψ with Formula 40.
- Verification of runner efficiency with Formula 45.
- Verification of the hydraulic efficiency of the turbine, with Formula 47 when $\eta_d = 80\%$.
- Determination of the pitch t and the chord length L.

Note *)

TABLE No. 1
CHARACTERISTIC VALUES FOR AXIAL-FLOW HYDRAULIC TURBINES

Head (H), in m	5	20	40	50	60	70
No. of Blades	3	4	5	6	8	10
(D_0/D_1)	0.3	0.4	0.5	0.55	0.6	0.7
n_s (approx.)	860	700	500	350	300	250